
# NASA's Moon-to-Mars Planetary Autonomous Construction Technology Project: Overview and Status

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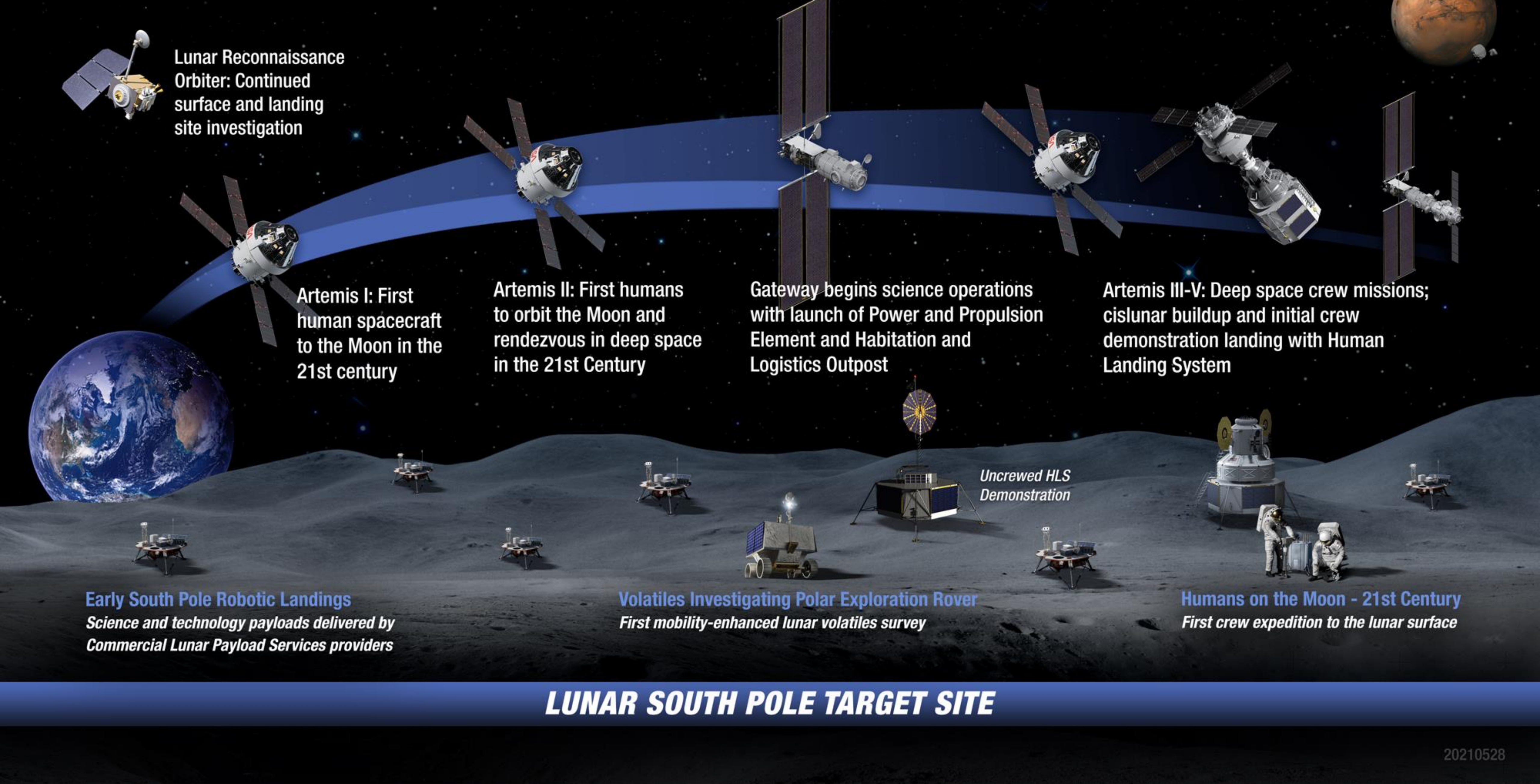
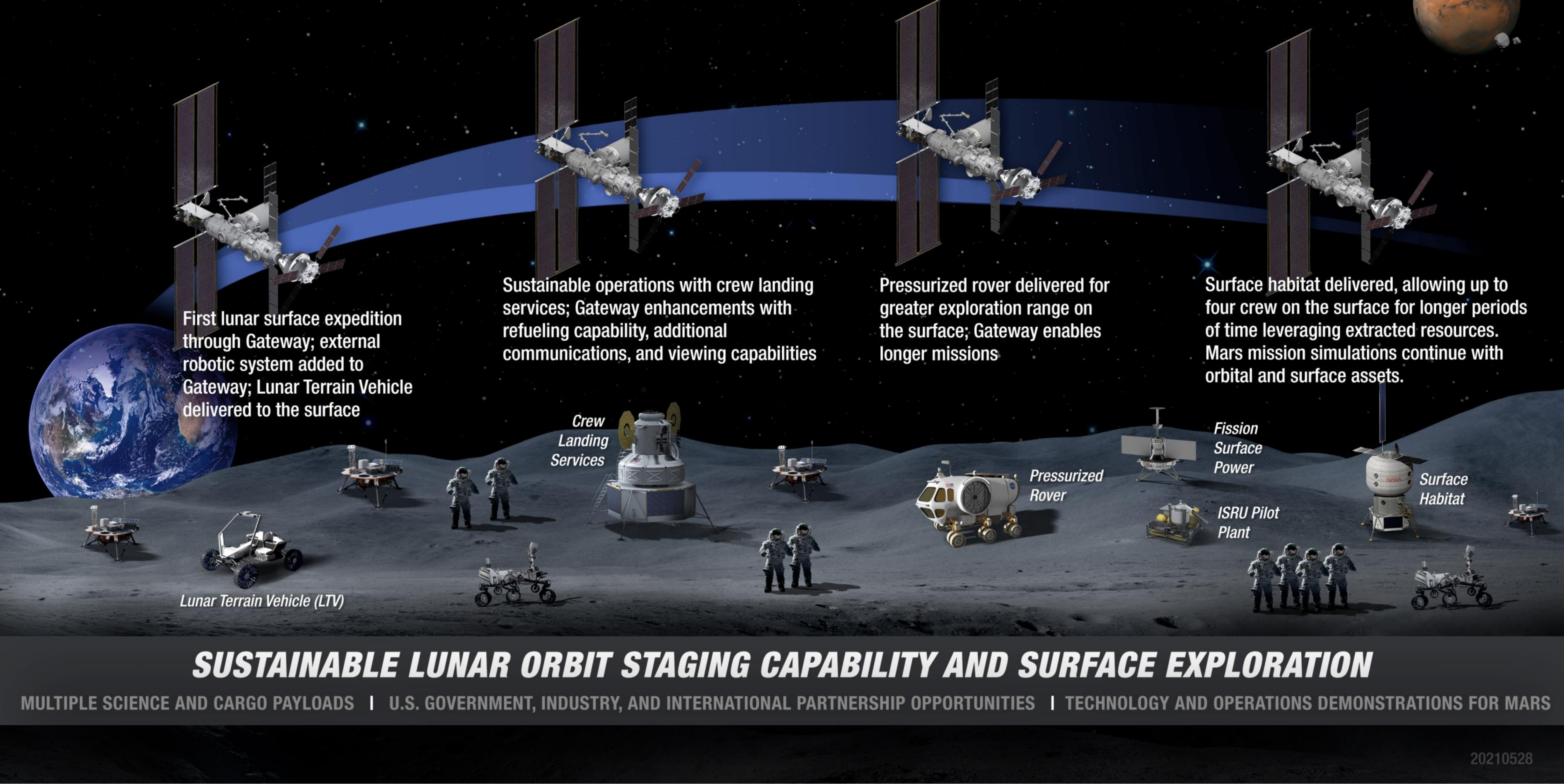
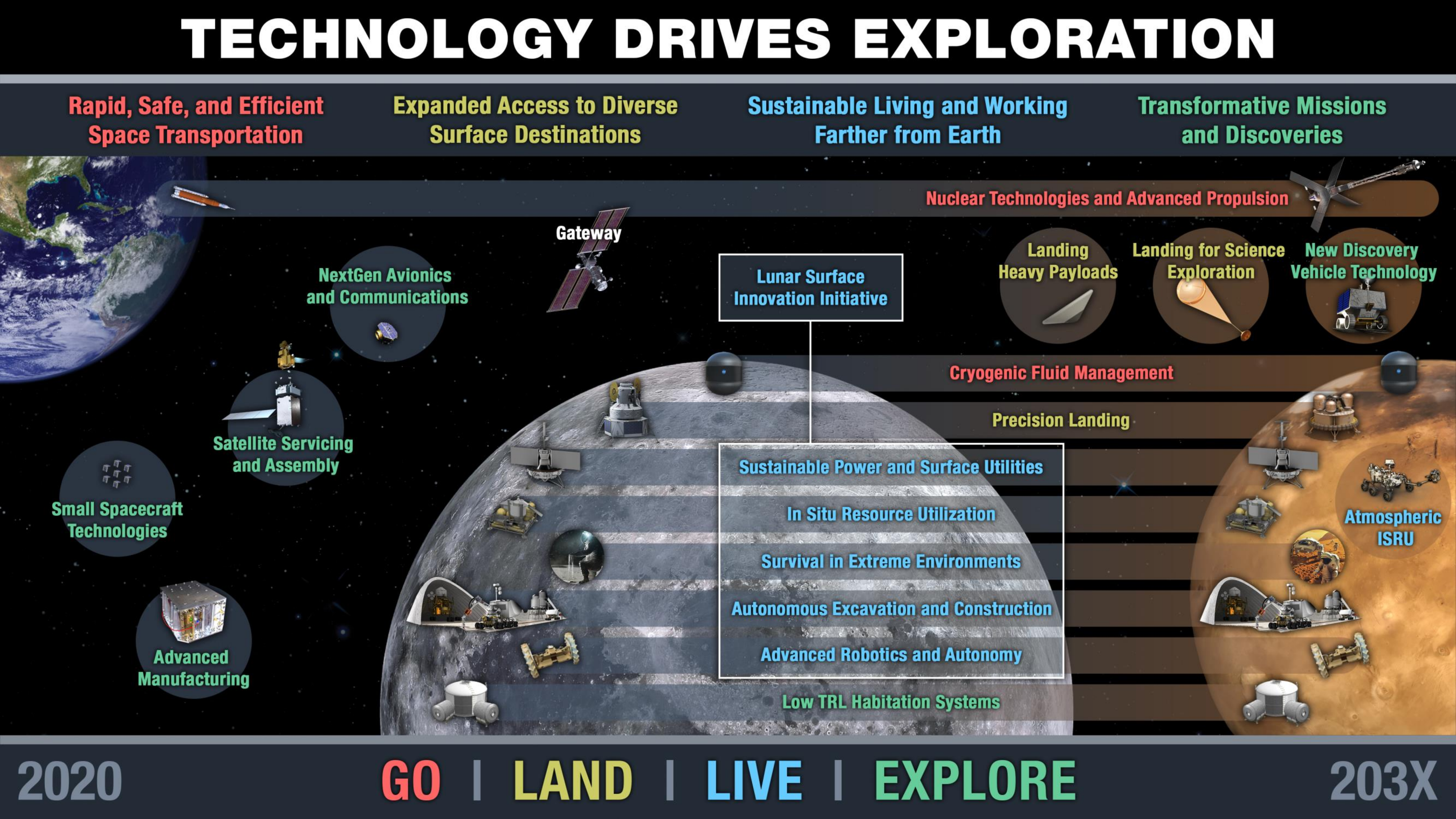
# Artemis: Landing Humans On the Moon



# Artemis Base Camp Buildup





TECHNOLOGY DRIVES EXPLORATION
Rapid, Safe, and Efficient Space Transportation
Expanded Access to Diverse Surface Destinations
Sustainable Living and Working Farther from Earth
Transformative Missions and Discoveries
Nuclear Technologies and Advanced Propulsion
Gateway
NextGen Avionics and Communications
Lunar Surface Innovation Initiative
Landing Heavy Payloads
Landing for Science Exploration
New Discovery Vehicle Technology
Satellite Servicing and Assembly
Small Spacecraft Technologies
Advanced Manufacturing
Cryogenic Fluid Management
Precision Landing
Sustainable Power and Surface Utilities
In Situ Resource Utilization
Survival in Extreme Environments
Autonomous Excavation and Construction
Advanced Robotics and Autonomy
Low TRL Habitation Systems
Atmospheric ISRU
2020
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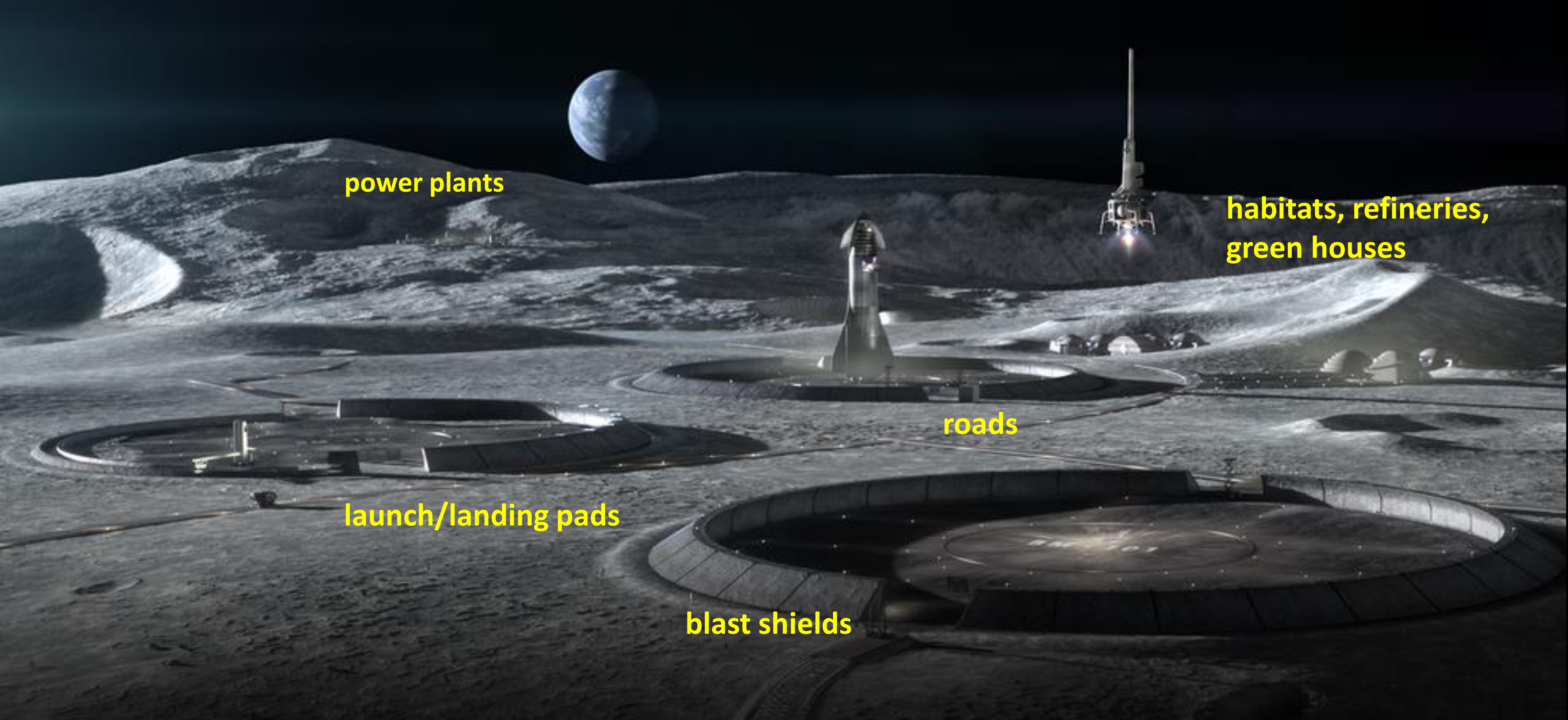
203X

# Building a Sustainable Presence on the Moon

- What infrastructure are we going to need?



# Moon-to Mars Planetary Autonomous Construction Technologies (MMPACT) Overview

## GOAL

**Develop, deliver, and demonstrate on-demand capabilities to protect astronauts and create infrastructure on the lunar surface via construction of landing pads, habitats, shelters, roadways, and blast shields using lunar regolith-based materials.**

## MMPACT is structured into three interrelated elements:

1. **Olympus Construction Hardware Development**
2. **Construction Feedstock Materials Development**
3. **Microwave Structure Construction Capability (MSCC)**

## OBJECTIVES

- **Develop and demonstrate additive construction capabilities for various structures as materials evolve from Earth-based to exclusively *In Situ* Resource Utilization (ISRU)-based.**
- **Develop and demonstrate approaches for integrated sensors and process monitoring in support of *in situ* verification & validation of construction system and printed structures.**
- **Test and evaluate Olympus and MSCC products for use in the lunar environment.**
- **Validate that Earth-based development and testing are sufficient analogs for lunar operations**

# MMPACT – Current Partners

**NASA Centers**
- MSFC
- LaRC
- KSC
- JPL

**OGA Leveraging**

Potential:
- Innovation Unit US Air Force (AF)

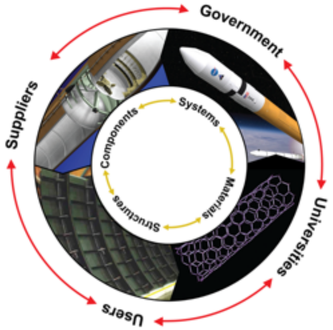
Contributing:
- AF Civil Engineering Center
- AF Special Operations Command
- Defense Innovation Unit
- Texas Air National Guard
- USAF

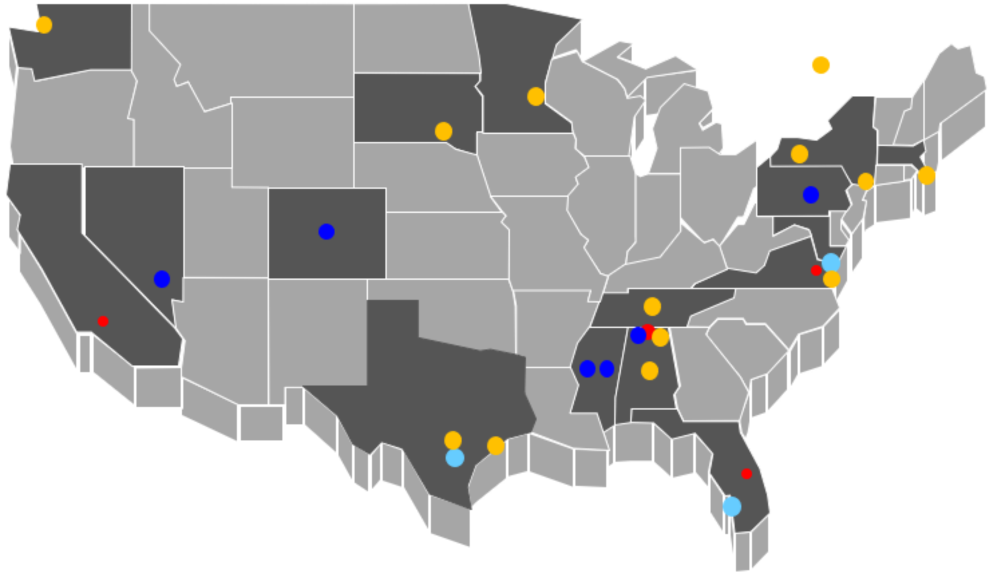
**Public/Private Partnerships**
- Dr. Holly Shulman
- ICON Build
- Radiance Technologies
- RW Bruce Associates, LLC
- Blue Origin
- Jacobs Space Exploration Group
- JP Gerling
- Logical Innovations
- Microwave Properties North
- MTS Systems Corp.
- Southeastern Universities Research Association
- Southern Research
- Space Exploration Architecture (SEArch+)
- Space Resources Extraction Technologies
- Sioux Tribes
- Astroport

**Technology Providers/ Contributing Partners: Academia**
- Colorado School of Mines
- Drake State
- Mississippi State University
- Pennsylvania State University
- University of Mississippi
- University of Nevada Las Vegas

**SBIR/STTR**
- Construction Scale Additive Manufacturing Solution

**Potential Customer**
- Artemis



**Collaborative multidisciplinary partnerships to leverage fiscal resources, ideas, knowledge & expertise.**

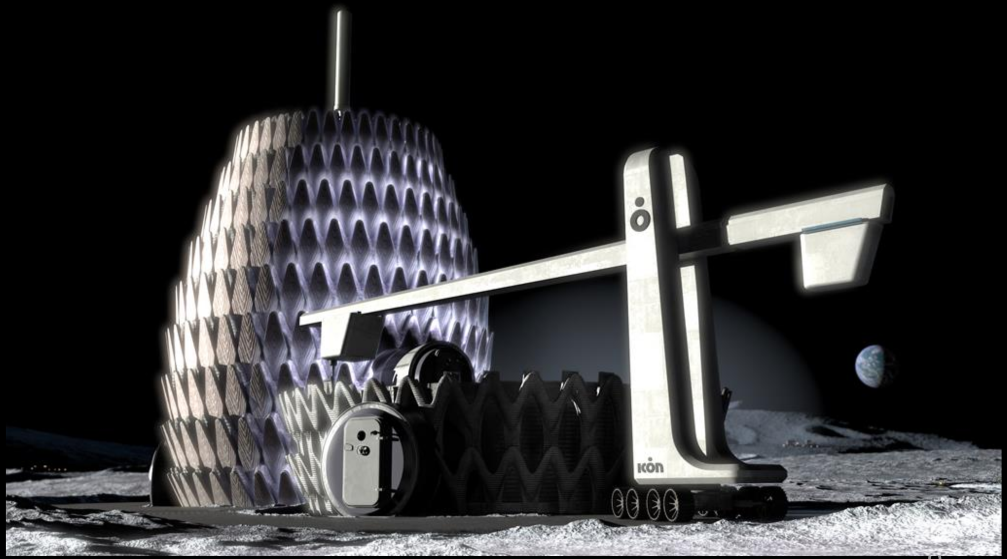
# Autonomous Construction: Materials and Concepts for the Lunar Outpost

## Regolith-based Materials and Processes:

- Cementitious
- Geopolymers/Polymers
- Thermosetting materials
- Regolith Melting/Forming
- Laser sintered
- Microwave sintered

Bjarke Ingels Group Concept courtesy of ICON's Architecture Study


Image courtesy of ICON

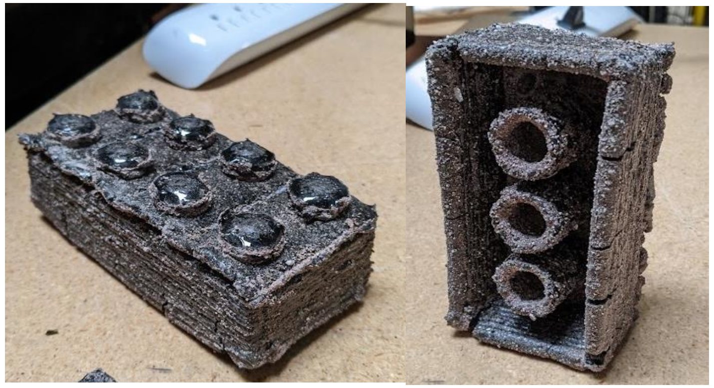


SEArch+ Concept courtesy of ICON's Architecture Study

# Early Process Development Results

- Controlled molten extrusion under vacuum from ICON's molten regolith extrusion system.

- Vacuum-cast specimens, using ICON's molten regolith extrusion system.
- Laser direct energy deposition process building a layer of a test specimen (brick).
- Laser direct energy deposition, additively constructed test specimen (brick).



- First high vacuum microwave sintering result showing solid sintered CSM-LHT-1G tile

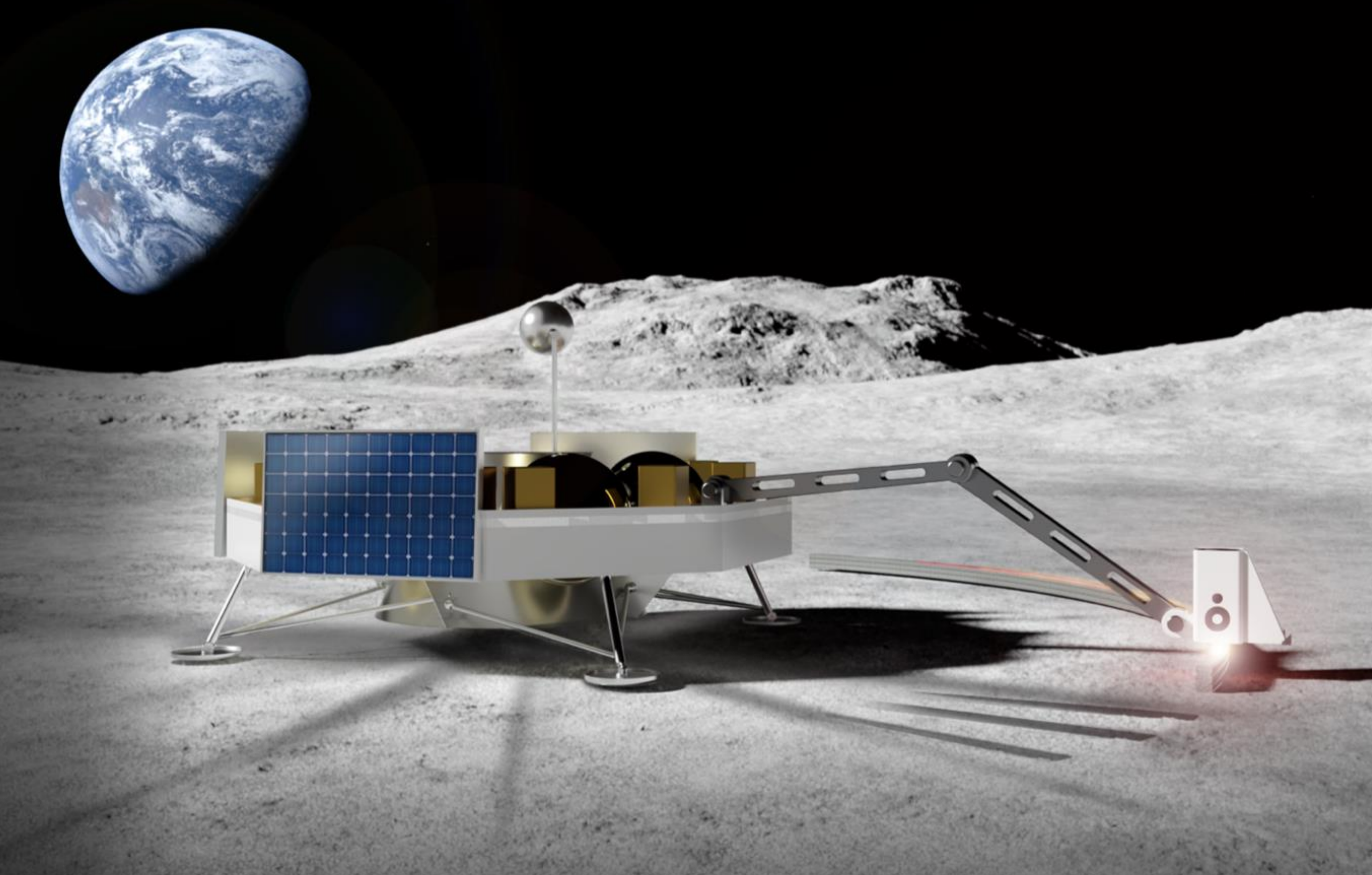
# Initial Construction Technology Demonstration Mission

**Objectives:**

- Establish a proof of concept for one or more materials/processes.

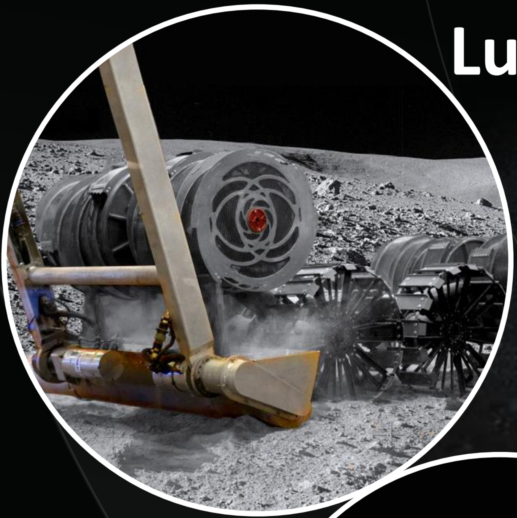
- Validate general material use and process viability for longer-term and more complex missions.

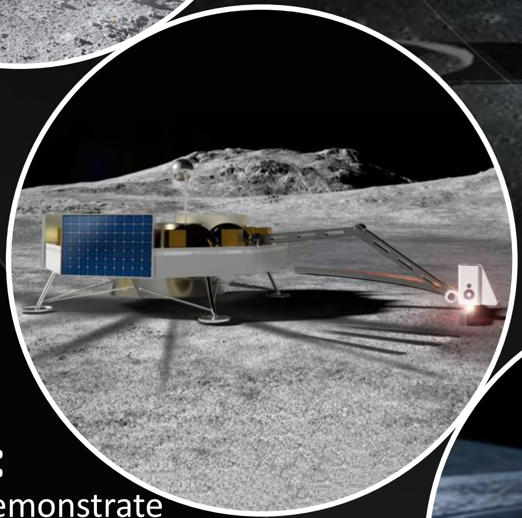
- Address technology gaps required for advancements in future autonomous construction capabilities.



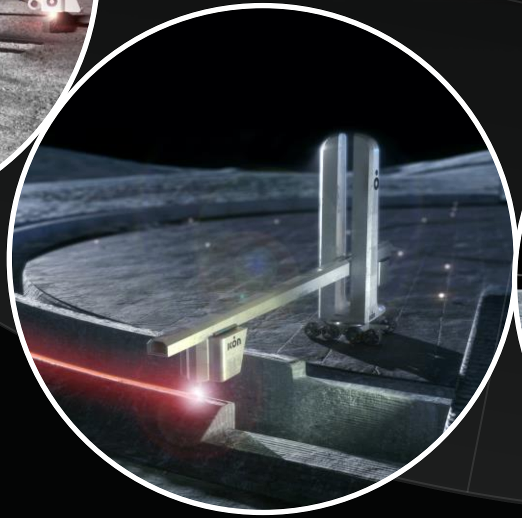
# Lunar Construction Capability Development Roadmap

**Phase 4:** Complete build-out of the lunar base per the master plan and add additional structures as strategic expansion needs change over time.

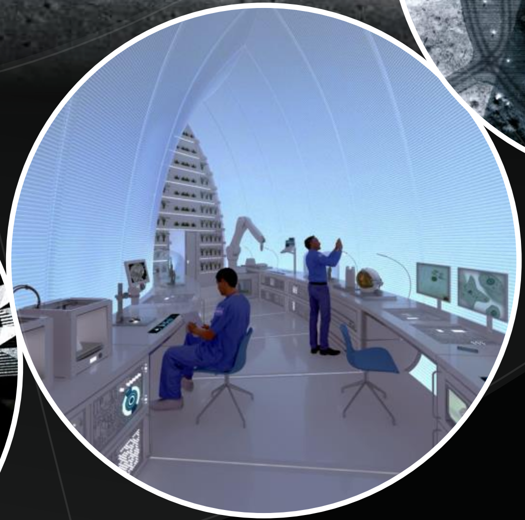




**Phase 1:**
Develop & demonstrate excavation & construction capabilities for on-demand fabrication of critical lunar infrastructure such as landing pads, structures, habitats, roadways, blast walls, etc.



**Phase 2:** Establish lunar infrastructure construction capability with the initial base habitat design structures.



**Phase 3:** Build the lunar base according to master plan to support the planned population size of the first permanent settlement (lunar outpost).

# MMPACT

## MOON TO MARS PLANETARY AUTONOMOUS CONSTRUCTION TECHNOLOGY

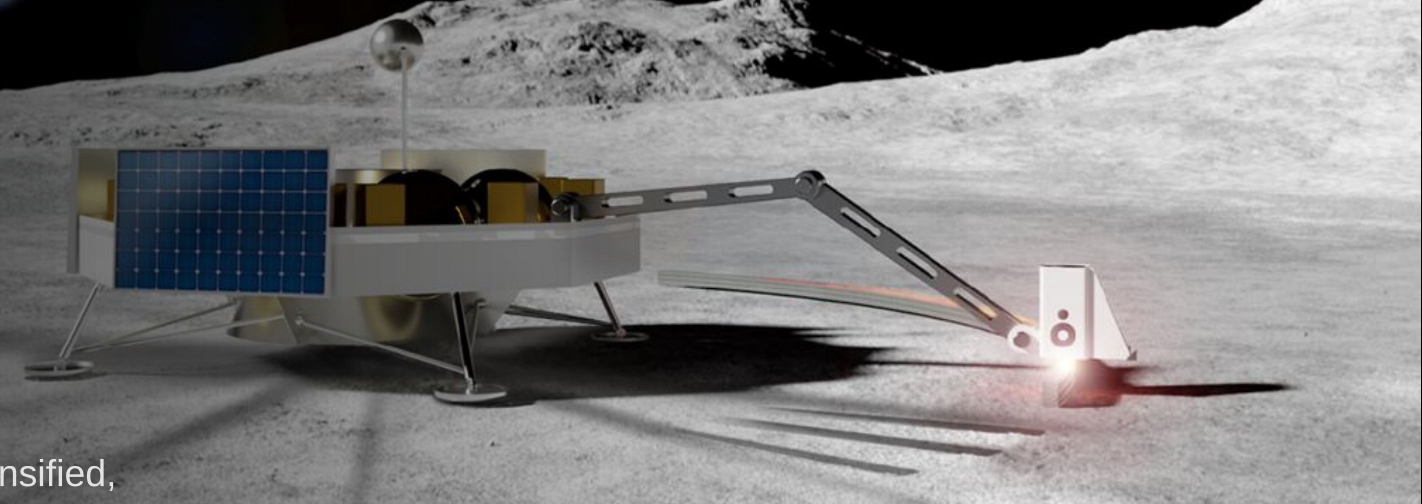

NASA
www.nasa.gov/spacetech

# Initial Construction Technology Demonstration Mission, Candidate for Flight on DM-1 ( 2026 )

MMPACT

## Construction Roadmap

- Demonstrate downselected construction technique utilizing ISRU materials at small scale from lander base (horizontal and vertical subscale “proof of concept” elements )
- Results are critical to inform future construction demonstrations & characterize ISRU-based materials and construction processes for future autonomous construction of functional infrastructure elements
- Demonstration of remote/autonomous operations
- Initial demonstration of instrumentation and material
- Validation that Earth-based development and testing are sufficient analogs for lunar operations
- Anchors analytical models
- ***Rationale:*** *Must prove out initial construction concept in lunar environment*



## Outcome

- **TRL 6** achieved for autonomous ISRU consolidation into densified, subscale horizontal and vertical demonstration products
- **TRL 9** for limited hardware and instrumentation that will be used on later missions

***PRELIMINARY PLANNING SUBJECT TO REVIEW***